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The Soft X-ray Variability and Spectrum of 1H0419–577from a long EUVE Observation

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ABSTRACT

The active galaxy associated with the hard X-ray source 1H0419–577 was observed with EUVE for about 25 days to obtain a long, contiguous light curve and an EUV spectrum. An EUV source was detected which was about as bright as the AGN and was later identified as an AM Her type system (Halpern et al. 1999). The AGN showed variations as large as a factor of two over 5-10 day time scales and occasionally varied by 20-30% in $< 0.5 day$. The spectrum is dominated by a continuum that is poorly fit by a simple power law. There are possible emission lines without positive identifications but the lines are likely to be spurious.

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1. Introduction

There were less than 10 active galactic nuclei (AGN) detected in the EUVE all-sky survey that were bright enough to be considered detected unambiguously (Marshall, Fruscione, & Carone 1995). Of these, only a few have broad lines and are bright enough to be detected well using the EUVE spectrometer. There has been significant controversy regarding the extreme ultraviolet (EUV) spectra of the few AGN that have been observed. While there are claims of possible emission lines in some active galaxies (NGC 5548: Kaastra et al. (1995); Mrk 478 and Ton S180 Hwang, C.-Y. & Bowyer, S. 1997), there is also evidence that the AGN spectra are dominated by continua and that any lines must very weak (Mrk 478: Marshall et al. 1996; RXJ0437-4711, Halpern & Marshall 1996; NGC 5548: Marshall, et al. 1997). These EUVE observations often lasted many days so that detailed light curves using the EUVE DS imager showed significant variability.

One of the brightest of the broad line AGN detected in the EUVE all-sky survey was 1H0419–577 which is identified LB 7127 (Brissenden 1989). A 2-month ROSAT HRI light curve and two 1-day ASCA observations are presented by Turner, et al. (1998), who show that the X-ray spectrum breaks near 0.7 keV to a very steep spectrum ($\Gamma > 3$) at low energies and the soft X-ray flux was variable on a time scale of $\simeq 1$ day.

A long EUVE observation was conducted to determine the EUV spectrum of this Sy 1.5 galaxy and to study the variability of its EUV flux. The flux varied at the 20-30% level on a time scale of days and appears to show a peak in the power density spectrum at period of 5.8 days. The EUV spectrum is dominated by continuum but may have line features that cannot yet be securely identified which may be spurious. The EUV spectrum of a nearby AM Her star is similar: a dominant continuum shows what may be line features. We argue that these lines have no plausible identifications and are also spurious.

2. Deep Survey Imager Observations

In order to optimize the signal/noise at short wavelengths in the short wavelength (SW) spectrometer data, the telescope was pointed 0.3°off-axis in the direction of the +X axis of the SW spectrometer channel. This approach was used successfully in several previous AGN observations (Marshall et al. 1996 and Marshall, et al. 1997). In addition, the telescope was "nodded" by ±30 ″along the $+Y$ axis of the SW spectrometer in order to null out a fixed pattern background that is apparent in long SW exposures. The fixed pattern background was first noticed in an observation of NGC 5548 (Marshall, et al. 1997).

The EUVE DS image of the field unexpectedly showed a second EUV source about 4′away from the AGN position with a count rate comparable to that of the AGN (see figure 1). Halpern et al. 1999 showed that this second source is an AM Her star and gives a finding chart along with a discussion of the identification of the active galaxy. See Halpern et al. 1999 and Turner, et al. (1998) for detailed discussions of the identification of the EUV and X-ray source. For this paper, we take the redshift to be 0.104 (Thomas, et al. (1998)) which we can confirm in a CTIO spectrum taken on 1998 January 4 (figure 2).

The EUVE DS/S was used to observe 1H0419–577 from 1997 December 15 to 1998 January 10 (TJD ≡ JD-2450000 = 798 to 824). For details of the EUVE spectrometer, see Abbott, et al. (1997). All data were selected so that the angle between the DS/S boresight and the local zenith angle was less than 102°, for which the minimum altitude of the line of sight (LOS) is 400 km. Using models of the H_2, He, and O_2 in the upper atmosphere, we estimate that there is less than 4% attenuation of the EUV flux for wavelengths shorter than 100 Å. The fraction of the observation where the line of sight grazes the Earth's limb is very small, so there should be no noticeable effects from atmospheric attenuation.

High background periods were eliminated by restricting the detector ADC count rate to less than 50 count/s. At this level, the Primbsch and dead time corrections to the count rates are less than about 25% at any time (see Marshall 1999b and Miller-Bagwell & Abbott 1997 for a discussion of these corrections).

A likelihood method was used to estimate the count rate, taking all known count rate effects into account (see Marshall et al. 1996 and Marshall 1999b). This method uses the known point spread function (PSF) to obtain the optimum signal/noise in each time interval. The PSF was derived from an observation of the bright BL Lac object PKS 2155–304 (Marshall et al. 1999a).

The resultant light curve of 1H0419–577is shown in figure 3. The average count rate was 0.00826 $\pm$ 0.0005 count/s. The error bar reflects only statistical uncertainties; systematic uncertainties are probably of order a few percent due to residual count rate correction uncertainties.

The power density spectrum (PDS) of the light curve is shown in figure 4. There appears to be a feature which corresponds to a period of about 5.8 days. If this period corresponds to Keplerian motion at the marginally stable orbit of an accretion disk in a Schwarzschild metric, then the central object would have a mass of order $9 \times 10^8 M_\odot$. The Eddington limit for such a massive black hole would be about 10^{47} erg/s; the optical and X-ray luminosities are of $\sim 10^{45}$ erg/s but the bolometric luminosity may be a factor of 10 higher due to the strong soft X-ray flux which dominates the spectral energy distribution (Turner, et al. (1998)).

3. Spectrometer Observations

A simple aperture extraction method was used for the 1996 observation because the cross dispersion profile is narrow when the target is only 0.3° off axis. A 10 pixel (0.0121°) fixed width aperture size was used for the source region and two 20 pixel regions on either side of the spectrum were used to estimate background. The spectra of the AGN and the nearby AM Her star are shown in figure /reffig:spectrum. The net exposure time in the spectrometer channel was 684179 s.

The spectra were then corrected for absorption by the cold interstellar medium (ISM), comprised predominantly of H but including 9% HeI and 1% HeII. The HI column density was set to 1.5 $\times 10^{20}$ cm^{-2} but is not well known. Without simultaneous coverage by an X-ray spectrometer such as ASCA over much of the EUVE spectrum observation, it is difficult to make a joint fit to determine a single power law model and reduce the uncertainties on N_H. The best fit spectral index for a power law model given by $f_\nu \propto \nu^{-\alpha}$ is $\alpha = 3$. The corresponding (unabsorbed) normalization at 80Å is 0.0016 $\pm$ 0.00017 ph cm^{-2} s^{-1} Å^{-1}. Reducing N_H to 1.0 $\times 10^{20}$ cm^{-2} reduces the ISM correction resulting in flatter spectra ($\alpha = 0.6$), while increasing N_H to 2.3 $\times 10^{20}$ cm^{-2} gives a steeper spectrum ($\alpha = 9$). The χ^2 is high in all power law fits and the probability that random data would give such high chi^2 values is always less than 0.002%. In figure 6 these models are compared to the AGN spectrum in the observed frame.

There are several features in the AGN spectrum that give rise to the poor residuals. There are two possible line features in the AGN spectrum. The rest wavelengths of the AGN features are about 83.5 Å and 95 Å to within 0.5 Å. The lines do not correspond with known detector features, which would have been eliminated due to the detector nodding pattern, which would put the feature out of the extraction window for half of the observation exposure time. Light curves of the events in 1 Å regions (see figure 7) show no spikes that might indicate contamination by a cosmic ray or a temporary bright hot spot. If the lines are collisionally excited in a thin thermal plasma, then the lines have no obvious identifications that would not also be accompanied by brighter lines elsewhere that are not detected. Even eliminating the two data points giving the largest residuals (which are only

2.5σ above the model), the fits do not improve much; the pure power law models are still rejected at the 99% confidence level.

Similarly, there are two or three possible lines in the spectrum of the AM Her star which have no ready identifications. Spectra of other AM Her stars observed with EUVE do not generally show emission lines, so we argue that the features in the spectra of both the AGN and the AM Her star are spurious.

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Fig. 1.— Images of point sources from the EUV Deep Survey imaging detector. The tick marks are one arcminute apart. The three lobe structure of each image is normal for the optics and the off-axis angle of the observation.

Fig. 2.— An optical spectrum of LB 1727, the counterpart of the hard X-ray source known as 1H0419–577 taken with the CTIO 1.5m telescope on 1998 January 4 and 5.

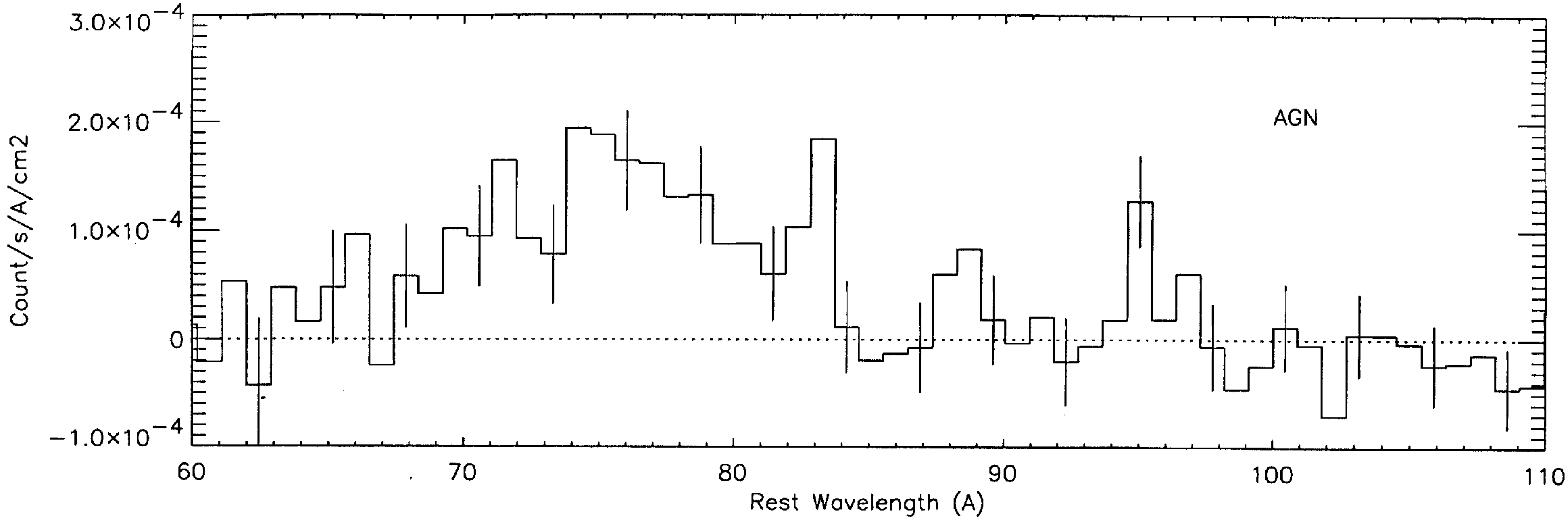
Fig. 3.— Time history of the count rate from 1H0419–577 obtained by the EUVE Deep Survey (DS) imaging detector averaged over one orbit intervals (about 1.5 hr each).

Fig. 4.— Power Density Spectrum of 1H0419–577 obtained from the light curve shown in figure 3. A possible periodic signal at 5.8 days is marked.

Fig. 5.— The soft X-ray spectra of the two EUV sources found in this observation with the EUVE SW spectrometer (see figure 1. *Top:* Spectrum of 1H0419–577. *Bottom:* Spectrum of the AM Her star 1EUVE J0425.6-5714.

Fig. 6.— The soft X-ray spectra of the AGN 1H0419–577. Several pure power law models were fit to the data with different assumed values of the interstellar medium column density.

Fig. 7.— Time history of the count rate from 1H0419–577 in several wavelength intervals in the source rest frame. The two narrow intervals represent possible spectral line features in the AGN spectrum shown in figure 5. These light curves show that the line features are not the results of cosmic ray hits or other variable background events. The broad wavelength interval is shown for comparison.



Count/s/A/cm2
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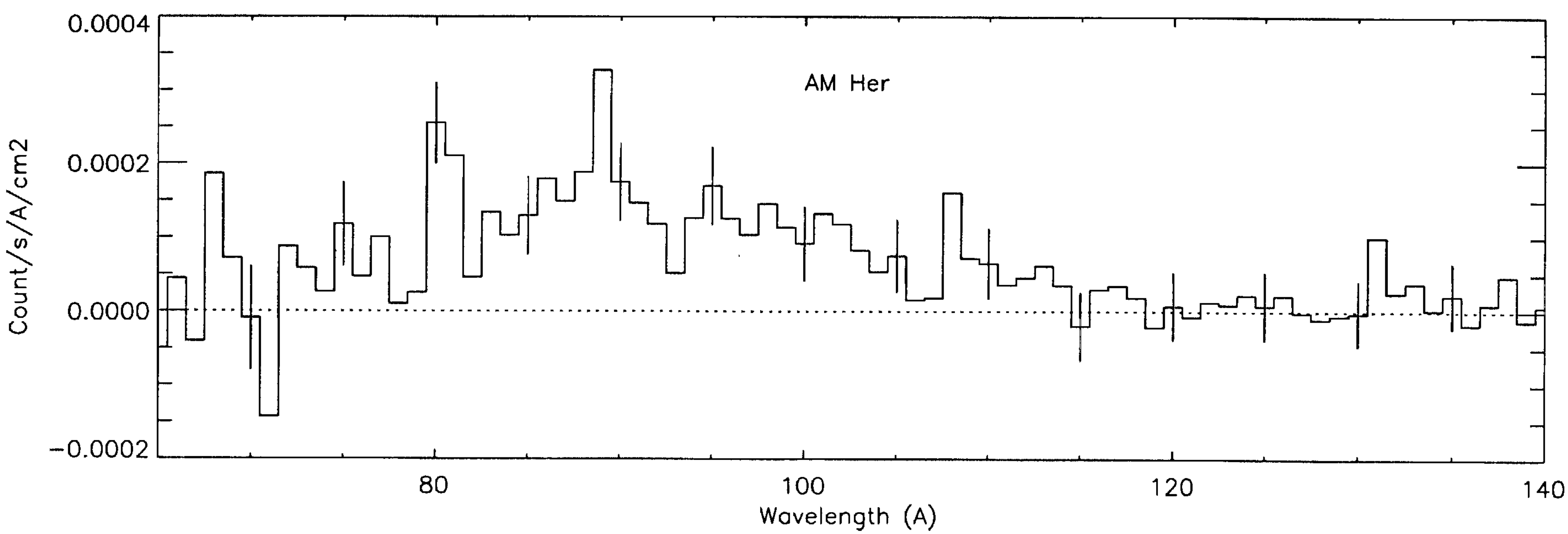
2.0×10^{-4}
1.0×10^{-4}
0
−1.0×10^{-4}
AGN
60
70
80
90
100
110
Rest Wavelength (A)



Count/s/A/cm2
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−0.0002
AM Her
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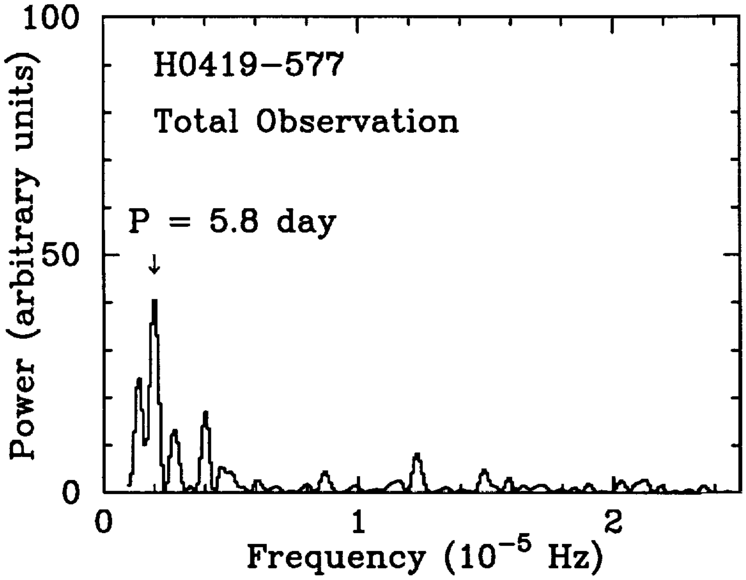
100
120
140
Wavelength (A)


H0419−577
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P = 5.8 day
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Frequency (10^{-5} Hz)
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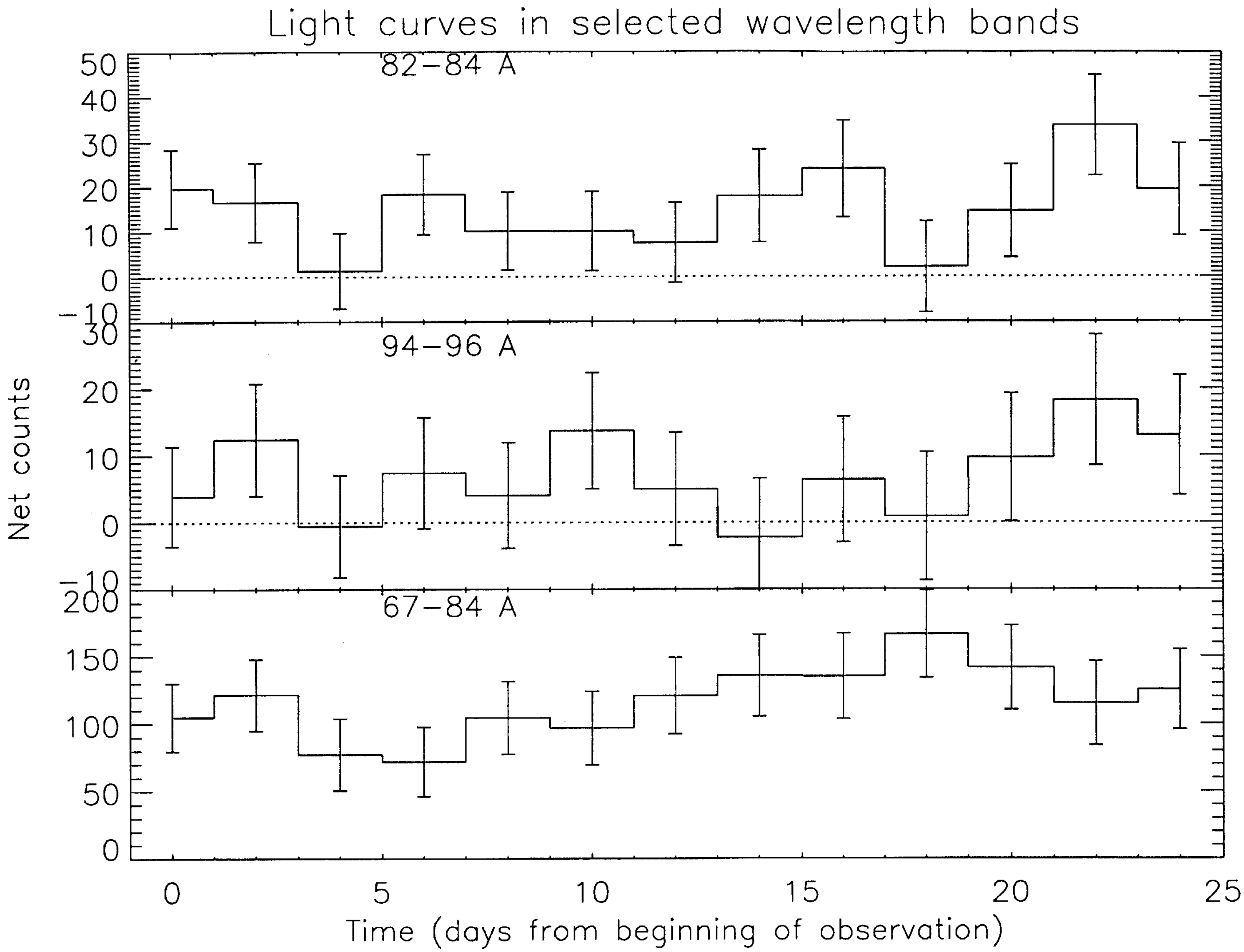
50
0
0
1
2


Light curves in selected wavelength bands
82−84 A
94−96 A
67−84 A
Net counts
Time (days from beginning of observation)
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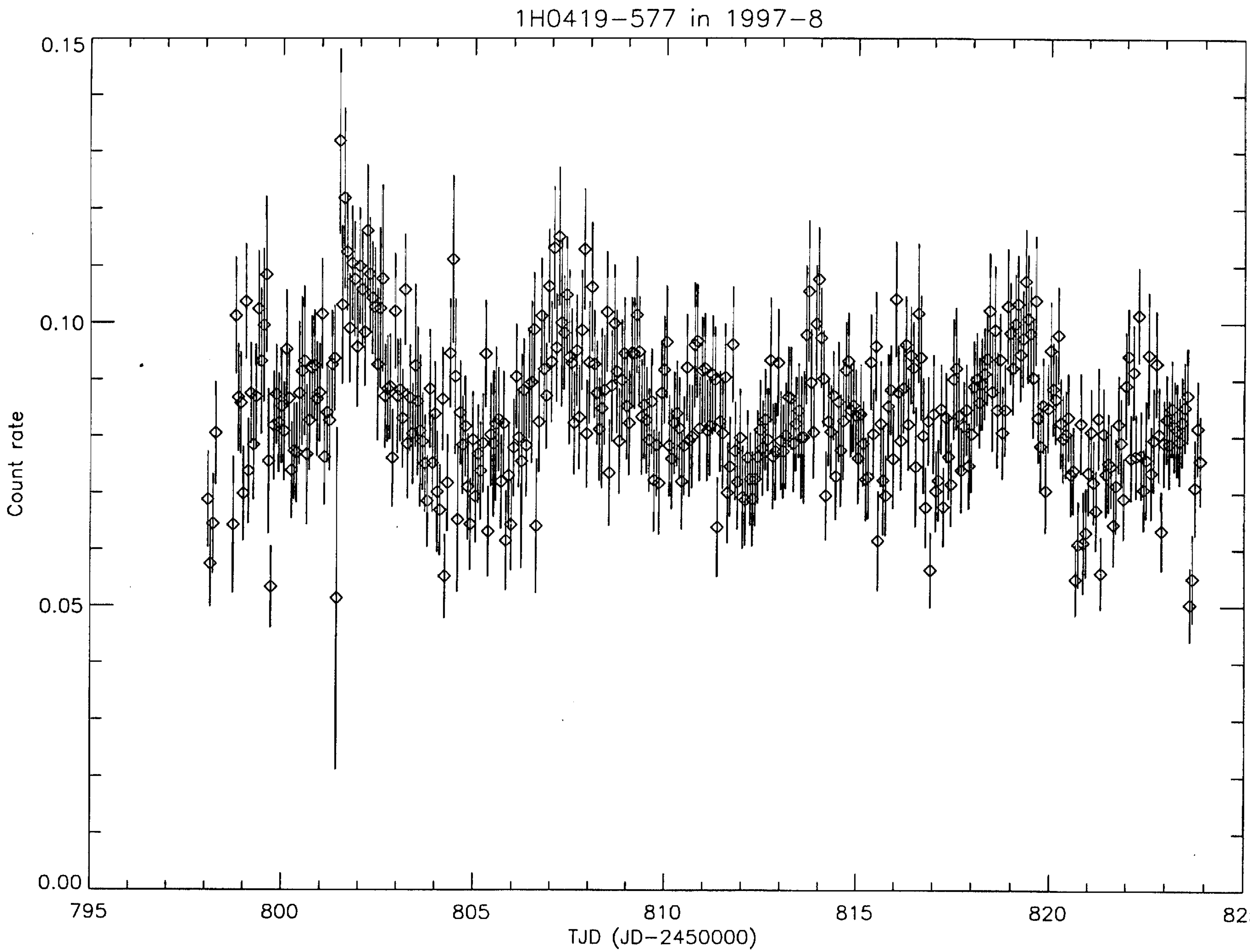
40
30
20
10
0
−10
30
20
10
0
−10
200
150
100
50
0
0
5
10
15
20
25


1H0419-577 in 1997-8
Count rate
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0.10
0.05
0.00
795
800
805
810
815
820
825
TJD (JD-2450000)

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